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# Educational Brief

Subject: Planetary Science, Astronomy

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# GALILEO PROBE: FIRST RESULTS

## The Most Difficult Atmospheric Entry in the Solar System was Successfully Accomplished!

After a six year journey through the solar system and after being inexorably accelerated to a speed of 170,700 km per hour (106,000 mph) by Jupiter's gravitational pull, the Galileo Probe successfully entered Jupiter's atmosphere at 22:04 UT (2:04 P.M. PST) on December 7, 1995. During the first two minutes, near-probe air temperatures twice as hot as the Sun's surface and deceleration forces as great as 230 g's (230 times the acceleration of gravity at Earth's surface) were produced as the Probe was slowed down by Jupiter's atmosphere.

During the parachute-descent phase of the mission, the Galileo Probe successfully studied the atmosphere of Jupiter with seven scientific experiments and radioed its findings to the Galileo Orbiter, which was 215,000 km (134,000 miles) overhead. The Galileo Probe and Orbiter separated on July 13, 1995 and both arrived at Jupiter on Dec. 7 on slightly different trajectories. **The Probe**, which **did not include a camera**, transmitted data for 57.6 minutes until about 200 km (125 miles) below the visible cloud tops, where the communication system failed due to the high temperatures.

***Hubble Space Telescope image of giant Jupiter obtained in October 1995 – the last sharp view before the Probe's entry – shows the entry location of the Galileo Probe.***

Telescopic observations from Earth helped determine the appearance of the Probe entry site at the time of entry and have monitored its changing appearance over time. Such observations are vital for placing the Galileo Probe measurements — taken at one location on the planet — in the context of Jupiter as a whole. The initial results show the entry site to be a highly variable and dynamic region of Jupiter’s atmosphere. The Hubble Space Telescope image on this page shows the appearance of Jupiter in October 1995.

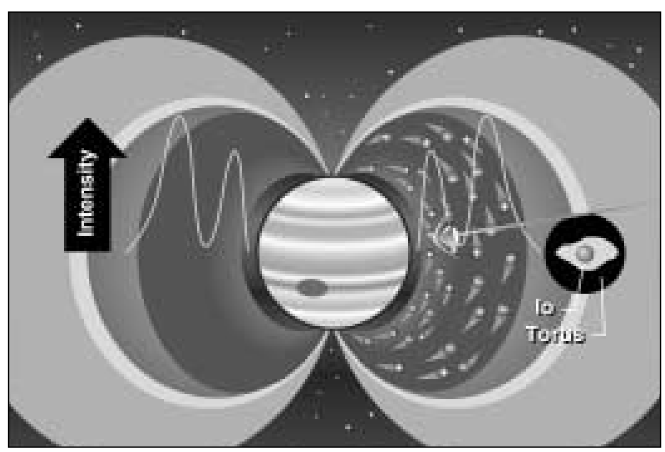
## A New Intense Radiation Belt

Three hours before atmospheric entry the only Galileo Probe scientific experiment *not* designed to study the atmosphere started to take measurements. The Energetic Particle Instrument (EPI) measured the radiation (high energy charged particles) in the previously unexplored inner regions of Jupiter's magnetosphere - the gigantic region about the planet in which Jupiter's magnetic field dominates the interplanetary magnetic field produced by the Sun.

Jupiter's radiation belts are so intense that the Galileo Orbiter must orbit quite high above Jupiter's cloud tops to avoid exposing its electronics to this damaging radiation.

The EPI discovered a new intense radiation belt between Jupiter's ring and the uppermost atmospheric layers. **The radiation is approximately 10 times as strong as in Earth's Van Allen radiation belts**, and includes high energy helium ions of unknown origin.

With further analysis, these discoveries will increase our understanding of Jupiter's magnetosphere and of its high frequency radio




***The Energetic Particle Instrument entered unexplored regions (beginning at Probe drawing) of Jupiter's radiation belts and discovered an intense inner belt as illustrated by the radiation intensity traces.***

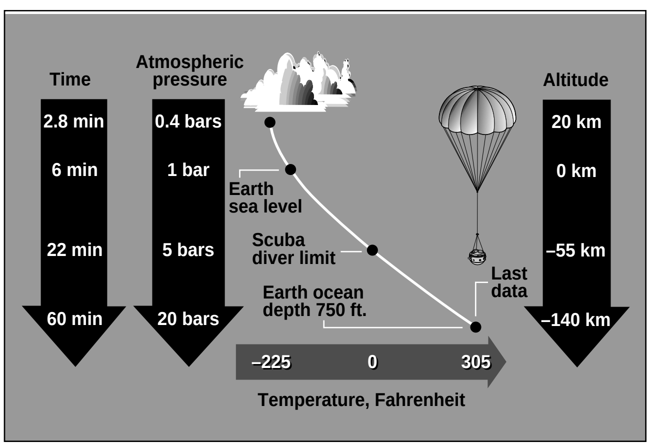
emissions. Many other celestial objects (e.g. stars, galaxies, and pulsars) have extensive magnetic fields and trapped radiation, so directly measuring the particularly strong magnetosphere of Jupiter can provide us with new understanding of the nature of these other objects as well.

## Measurements of Temperature, Pressure, and Vertical Winds Reveal Several Discoveries

As the Probe plunged into Jupiter's atmosphere, the Atmosphere Structure Instrument (ASI) measured the temperature, pressure, and density structure of Jupiter's atmosphere from the uppermost regions down through an atmospheric pressure of about 24 bars (24 times the atmospheric pressure at sea level on Earth, which equals the pressure at a depth of 230 meters – 750 feet – in the ocean) and a temperature of 305 degrees F (152 C). Such information is essential for understanding Jupiter's climate and for interpreting the results of the other experiments.

Initial results include finding that **upper atmospheric densities and temperatures are significantly higher than expected**. An additional source of heating beyond sunlight appears to be necessary to account for this result. At deeper levels the temperatures and pressures are close to expectations. The vertical variation of temperature in the 6-15 bar pressure range (about 100-150 km below visible clouds) indicates the **deep atmosphere is dryer than expected and is convective**.

The ASI's initial results have various important implications. Our ideas about the abundance and distribution of water on Jupiter will need to be reconsidered. The ASI measurements will increase our understanding of the escape of Jupiter's internal heat — a power source for its dynamic atmosphere. In addition, because of the convective nature of the lower levels of the atmosphere, the deep atmosphere must be well mixed, and composition measurements obtained by other instruments must be representative of the deeper levels of Jupiter's atmosphere as well.



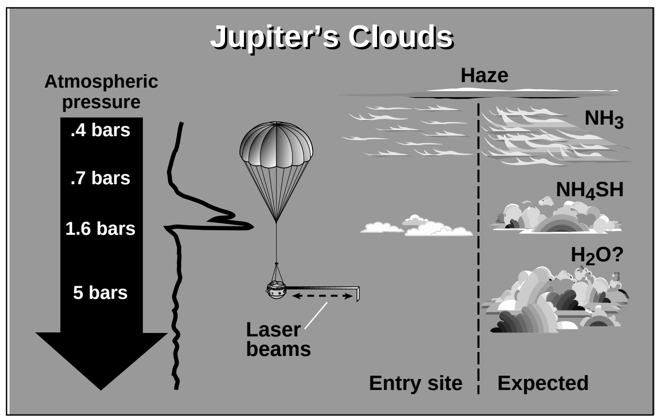

***The Atmosphere Structure Instrument measured Jupiter's atmospheric pressure and temperature during the Probe's one hour of direct measurements.***

## Visibility in the Atmosphere is Much Greater Than Expected in the Immediate Vicinity of the Probe Entry Site

Since we see clouds when we look at Jupiter from Earth, detecting and understanding the nature of Jupiter's clouds— the objective of the Nephelometer instrument (NEP) — can reveal a great deal about this cloud enshrouded world.

To scientists' surprise, **no thick dense clouds were found**, in contrast to expectations based on telescopic and flyby spacecraft observations of the planet and theoretical models. In fact, only very small concentrations of cloud and haze materials were found along the entire descent trajectory. One well-defined distinct cloud structure was found, and this appears to correspond to a previously postulated ammonium hydrosulfide cloud layer.

One important question which has arisen from these as well as other observations is whether the Probe's entry location is representative of most other regions of Jupiter. The cloud structure at the Probe Entry site appears to be very different than expected for Jupiter as a whole. Models of cloud formation on Jupiter may have to be revised.




***The Nephelometer's laser beams searched for cloud particles next to the Probe and found far less than expected. Trace at left schematically shows the amount of scattered light from the laser – a measure of the amount of cloud material.***

## Dense Cloud Detected Some Distance Away from the Probe Entry Site

On a clear day on Earth the brightness of the sky is quite large in the direction of the sun and less bright in other directions. On a very cloudy day, the sky is nearly equally bright in all directions and determining the direction to the sun can be difficult. The Net Flux Radiometer (NFR) has used this effect to locate an important cloud layer on Jupiter.

Large variations in the brightness of the sky in different directions were noticed until an abrupt drop-off in the variation occurred below a pressure level of 0.6 bars, indicating a cloud layer which is most likely the previously postulated ammonia cloud layer — believed to be the uppermost cloud layer on Jupiter. No other significant cloud layers were found— in particular, the tenuous cloud layer detected by the NEP (See "Visibility in the atmosphere...section) was *not* seen by this experiment. Moreover, the cloud seen by the NFR was not seen by NEP!

The explanation for this apparent contradiction is that the NEP measures cloud particles in the immediate vicinity of the Probe while the NFR measures clouds over a long distance. The simplest explanation for the results from these two cloud-detecting experiments appears to be that the clouds are patchy and that the Probe went through a relatively clear area.

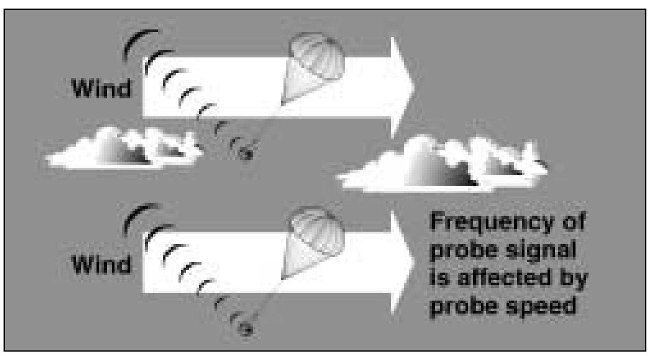
The NFR also measured variations of infrared "thermal" radiation. Heating of the NFR's cloud layer by heat escaping from the interior of Jupiter appears to also be occurring and may affect the nature of Jupiter's winds.

## Strong Winds Persist to Great Depth

Previous studies of Jupiter's cloud motions show that it has a very unusual wind system consisting of strong alternating east-west jet streams quite unlike Earth's wind systems. The origin of Jupiter's winds is not clear, in large part due to our inability to see below the uppermost clouds in the atmosphere.

Initial results from the Doppler Wind experiment indicate that **the winds below the clouds blow at 650 km/hour (400 mph) and are roughly independent of depth**. Winds at the cloud tops monitored by the Hubble Space Telescope are of similar strength. These results have profound implications.

It now appears that winds on Jupiter are probably not produced by heating due to sunlight, or by heating due to condensation of water vapor — two heat sources which power winds on Earth. A likely mechanism for powering the winds now appears to be the heat escaping from Jupiter's deep interior.




***The Doppler Wind Experiment, which measured the vertical variation of winds in Jupiter's atmosphere, found fierce winds even deep in the atmosphere!***

## Lightning on Jupiter Very Different than on Earth

Lightning in an atmosphere can provide evidence of thunderstorm-like activity which would be indicative of regions of strong atmospheric updrafts and rain. Production of certain chemical species, including complex organic molecules such as those that are the building blocks of life on Earth, can also depend on the amount of lightning activity.

On Earth we are accustomed to lightning discharges between the clouds and the ground. However, lightning discharges within clouds are by far the most common. On Jupiter, where no solid surface exists, lightning is believed to be occurring within the water clouds.

The Lightning and Radio Emission Detector searched for optical flashes and radio waves emitted by lightning discharges. **No optical lightning flashes were observed in the vicinity of the Galileo Probe**, but many discharges were observed at radio frequencies.

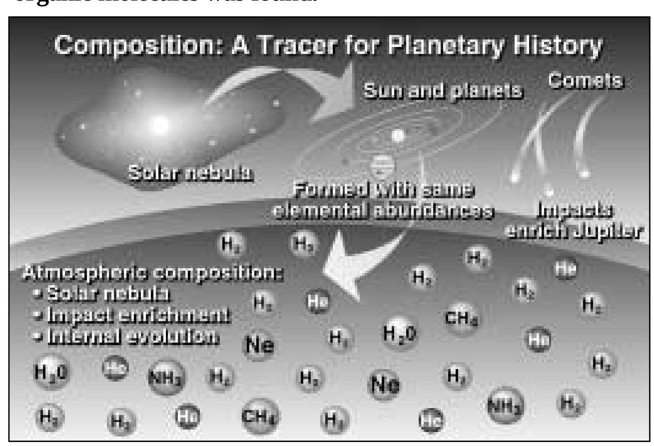
The form of the radio signals indicates that the discharges were far away (roughly one Earth diameter away), and that the lightning bolts are much stronger than Earth's. **Radio wave intensity suggests lightning activity is 3-10 times less common than on Earth**.

Initial analysis implies that lightning on Jupiter is very different than on Earth. The unusual form of the radio signals from the lightning indicates more work on lightning discharge physics on Jupiter is needed. Ideas of water cloud distribution, precipitation, and heat escape from Jupiter may need revision.

## Several Key Elements and Compounds Appear to be Less Abundant than Expected

Jupiter's strong gravitational grip trapped a sample of all of the ingredients making up the cloud of gas and dust from which the planets formed 4.5 billion years ago — unlike Earth where the lightest and most plentiful ingredients have largely escaped. From Jupiter's size and mass, astronomers have long known that it is almost entirely made of hydrogen and helium — the two most abundant elements in the universe as a whole. Precise measurements of the amounts of oxygen, carbon, neon, and nitrogen — the next four most abundant elements in the universe —, as well as helium and other less abundant ingredients, can not only have implications for understanding Jupiter today but can also provide clues to the planetary formation and evolution process.

The Neutral Mass Spectrometer (NMS) experiment’s objective was to accurately determine the composition of the atmosphere. **Initial results indicate the atmosphere has much less oxygen — mainly found as water vapor in Jupiter’s atmosphere — than the Sun’s atmosphere, implying a surprisingly dry atmosphere.** On the other hand, the amount of carbon — mainly found as methane gas — is highly enriched with respect to the Sun, while sulfur — in the form of hydrogen sulfide gas — occurs at about solar values. The abundance of nitrogen — in the form of ammonia gas — is still pending. The abundance of neon — a Noble or “inert” gas — is highly depleted. **Little evidence of organic molecules was found.**




***The Neutral Mass Spectrometer and Helium Abundance Detector found several key elements in nearly solar proportions in Jupiter's atmosphere, providing fundamental clues to Jupiter's formation and evolution.***

The Helium Abundance Detector experiment very accurately measured the abundance of helium in Jupiter's atmosphere. **The relative abundance of helium was found to be near that in the Sun**.

According to these first results, the six most abundant elements occur in widely varying proportions relative to values in the Sun. Planetary scientists had expected oxygen to be enriched relative to the solar value due to impacts by comets and other small bodies over the 4.5 billion year history of the solar system. The helium abundance was expected to be somewhat lower due to the internal evolution of Jupiter. Accounting for these results provides challenges and opportunities for refining our ideas about the formation and evolution of Jupiter and the solar system. The role of meteorology in producing the dryer atmosphere must also be considered.

## The Probe Apparently Entered a Rather Special Location on a Complex World

By observing the "heat radiation" from Jupiter at infrared wavelengths, astronomers using telescopes on Earth found the Probe entry site to be near the edge of a so-called infrared "hot spot" (see the infrared image on this page). These "hot spots" are believed to represent regions of diminished clouds on Jupiter. In fact, the entry site appears to be among the clearest and driest spots on the planet!

The Galileo Probe apparently entered Jupiter at a rather unique location. This uniqueness may account for some of the apparent surprises in the area of cloud structure and composition. However, because the deep atmosphere is apparently well mixed, the composition measurements should be representative of the deeper levels of Jupiter's atmosphere and its overall makeup.

Starting in the spring of 1996 after completing the transmission of the Galileo Probe data, the Galileo Orbiter will commence detailed observations of Jupiter's satellites, atmosphere, and magnetosphere. These atmospheric observations combined with telescopic monitoring from Earth will enable a generalization of the Galileo Probe's findings to other regions of the planet.

NASA's Ames Research Center near Mountain View, California managed the Galileo Probe project and conducted science and engineering studies enabling this most difficult atmospheric entry. Hughes Space and Communications Company built the Galileo Probe. NASA's Jet Propulsion Laboratory in Pasadena, California managed the overall Galileo Project and built the Galileo Orbiter.

Scientific and popular articles on the Galileo Probe mission will be produced in the coming months and years. Several additional resources with background information and the latest results are found below.

## Resources with Further Information:

**World Wide Web Sites:**

- Galileo Probe Homepage at NASA Ames:

**URL**: http://ccf.arc.nasa.gov/galileo_probe/

A fuller summary of the first results from the Galileo Probe, other Probe information, progress reports, and educational resources, including "The Galileo Probe Master", who will answer e-mail questions.

- Galileo Project Homepage at the Jet Propulsion Laboratory:

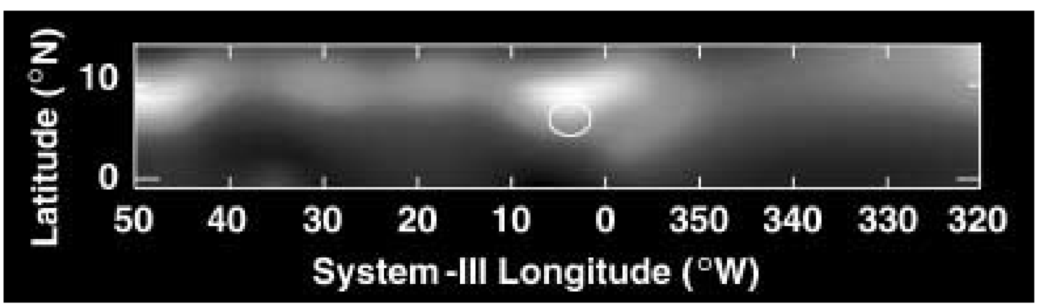
**URL**: http://www.jpl.nasa.gov/galileo

A wide range of information and educational resources on the Galileo Mission as a whole and the latest on the Galileo Orbiter's close encounters with the moons of Jupiter starting in the summer of 1996.

- "Online from Jupiter" Homepage:

**URL**: http://quest.arc.nasa.gov/jupiter.html

features personal journals from Galileo scientists and engineers, e-mail questions from K-12 students about the project (with answers from the Galileo Flight Team), classroom activities, and more.




***Infrared view of the Probe Entry Site (marked by circle) taken by a NASA telescope on Earth within moments of Probe entry time, showing the Probe entered near the edge of an infrared "hot spot" – believed to be a region of fewer clouds.***

## There are More Results to Come!

**This summary of scientific findings is the result of a first analysis of the returned data.** Refinements of the analysis will reveal new results as scientists continue the process of carefully converting the data returned from the Probe into useful scientific measurements and new theories.

In June 1996 the Galileo Orbiter will begin 18 months of very detailed imaging and other observations of Jupiter's four large intriguing moons and atmosphere along with further measurements of the magnetosphere.

**Other sources:**

*Galileo: Probe Into Jupiter,* NASA Educational Brief EB-117, 1995: For teachers and advanced students in grades 9-12. –Provides background information on Galileo Probe and Jupiter's atmosphere.

Galileo Outreach Office, M. S. 264-419, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109. Internet: askgalileo@gllsvc.jpl.nasa.gov –Additional information on Galileo educational materials for teachers.

*The Galileo Mission: Space Science Reviews*, Vol. 60, Nos. 1-4, Ed. C.T. Russell, 1992. Detailed description of Galileo Mission.